Astrophysically Motivated Bulge Disk Decompositions in SDSS

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Lackner & Gunn, MNRAS, submitted

Motivation

- Galaxies divide easily into spheroids and disks
- Morphology is strongly correlated with other properties (color, SF history, environment, etc.)
- Large surveys = lots of galaxies to correlate bulge/ disk properties with other measurements
  - Largest sample of B+D decomposed galaxies to date (see also Allen, et al., 2006; Benson, et al., 2007, Simard, et al. 2011)
  - Minimalist B+D models
  - Fast, robust 2-D model fitting

Sample

- 71,827 SDSS (data release 8) galaxies
  - Spectroscopic sample (m_r<17.77)
- redshift limits 0.003 < z < 0.05
  - 0.003—galaxies too big, 0.05—resolution too poor
- Remove edge-on galaxies (axis ratio < 0.25)
  - flat disk models are inaccurate

Fits

1. exponential profile $\mu \propto R$ (6 parameters)
2. de Vaucouleurs profile $\mu \propto R^{1/4}$ (6)
3. Sérsic profile $\mu \propto R^{1/n}$ (7)
4. exponential disk + de Vaucouleurs bulge (10)
5. exponential disk + exponential bulge (10)

- Best fit from weighted χ^2 minimization
- weights = 1/pixel variance = 1/((sky+signal)/gain)
- models fit in *r*; linearly scaled in *u*, *g*, *i*, and *z*

Two kinds of bulges: Classical and Pseudo-bulges

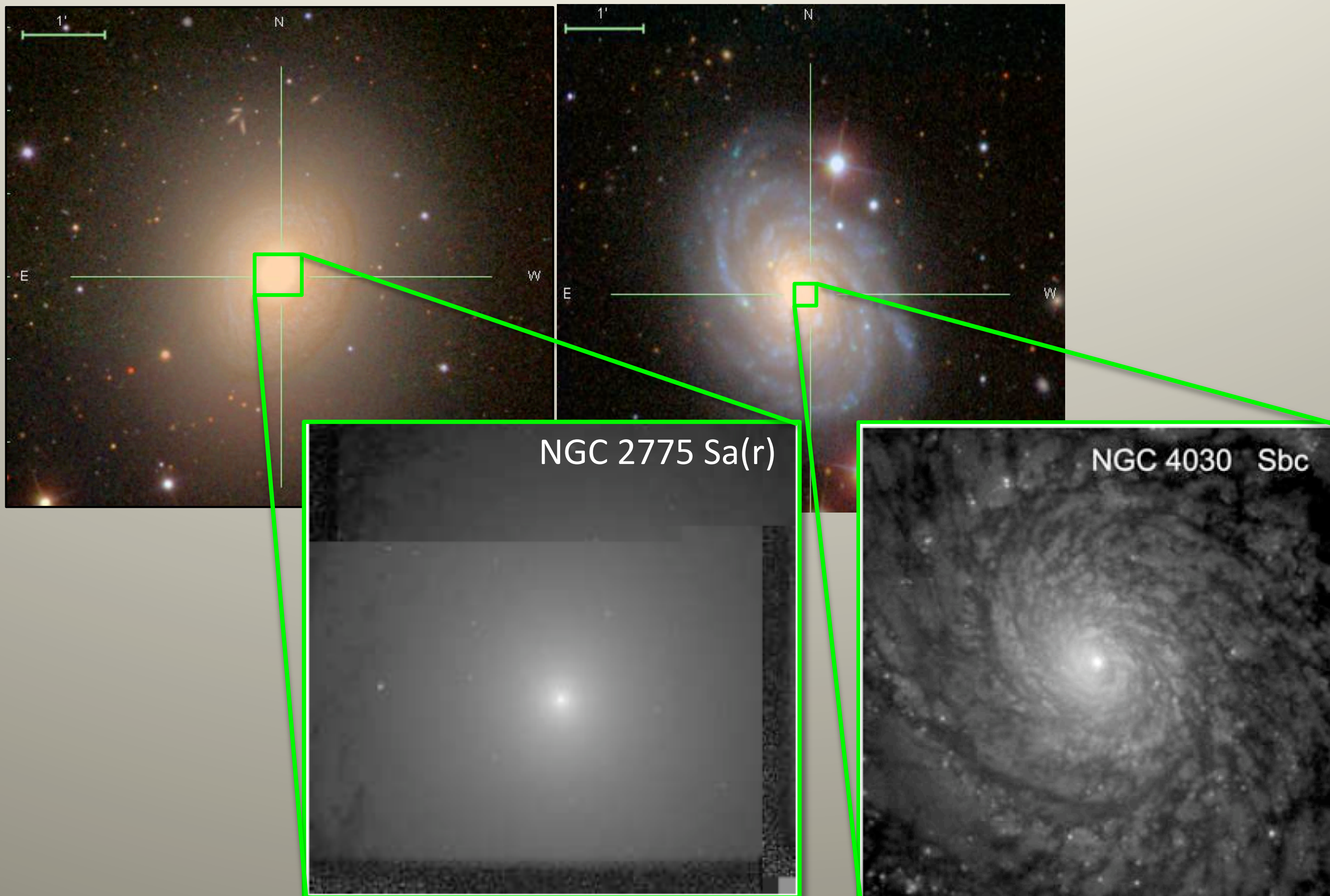
Classical bulges are "ellipticals that happen to have a prominent disk around them" (Renzini, 1999).

Elliptical-like bulges

Pseudo-bulges form by secular processes in a disk and retain a memory of their disky-origin. (Kormendy & Kennicutt, 2004).

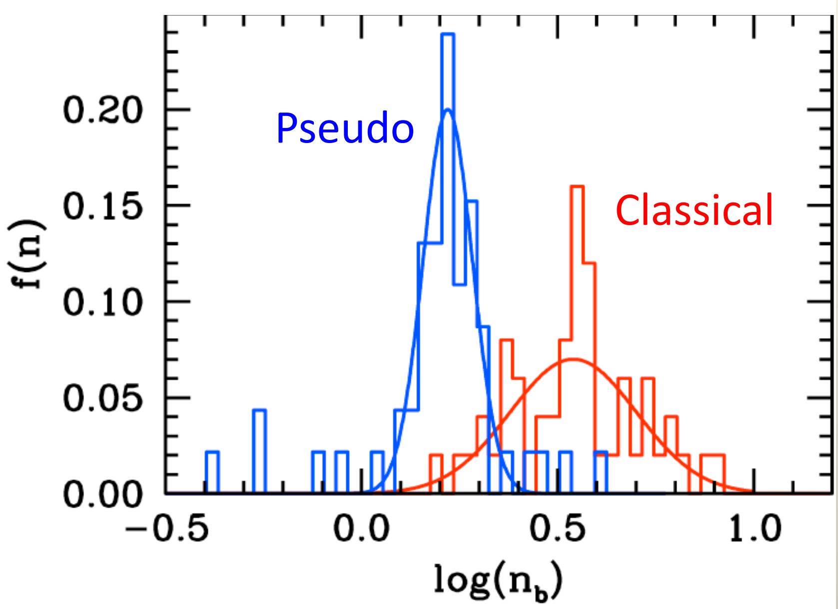
Disk-like bulges

Classical and Pseudo-bulges



Fisher, 2008

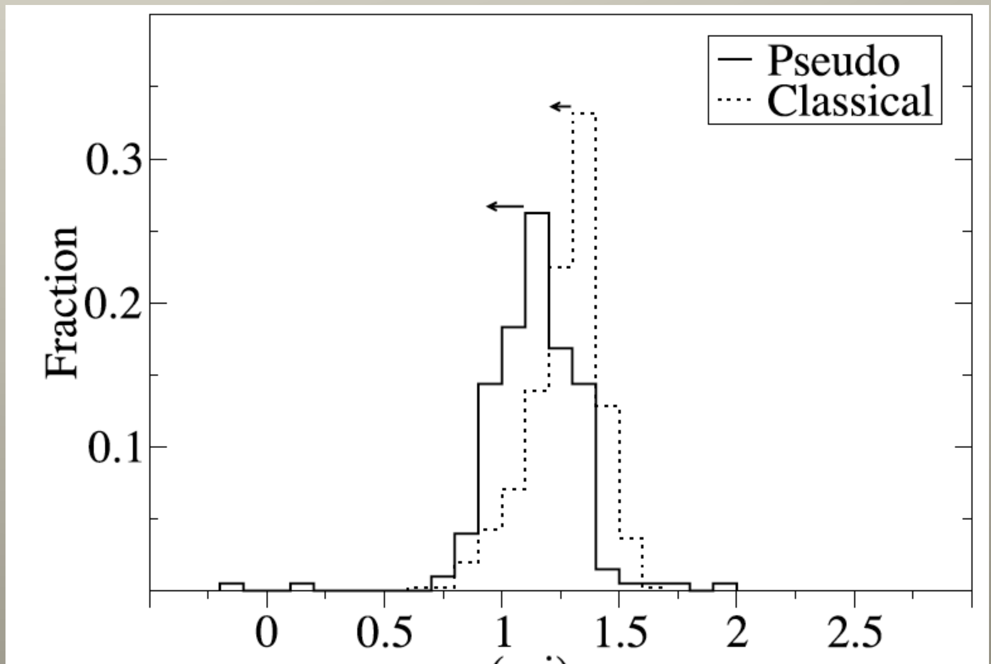
Kormendy & Kennicutt, 2004



Fisher, 2008

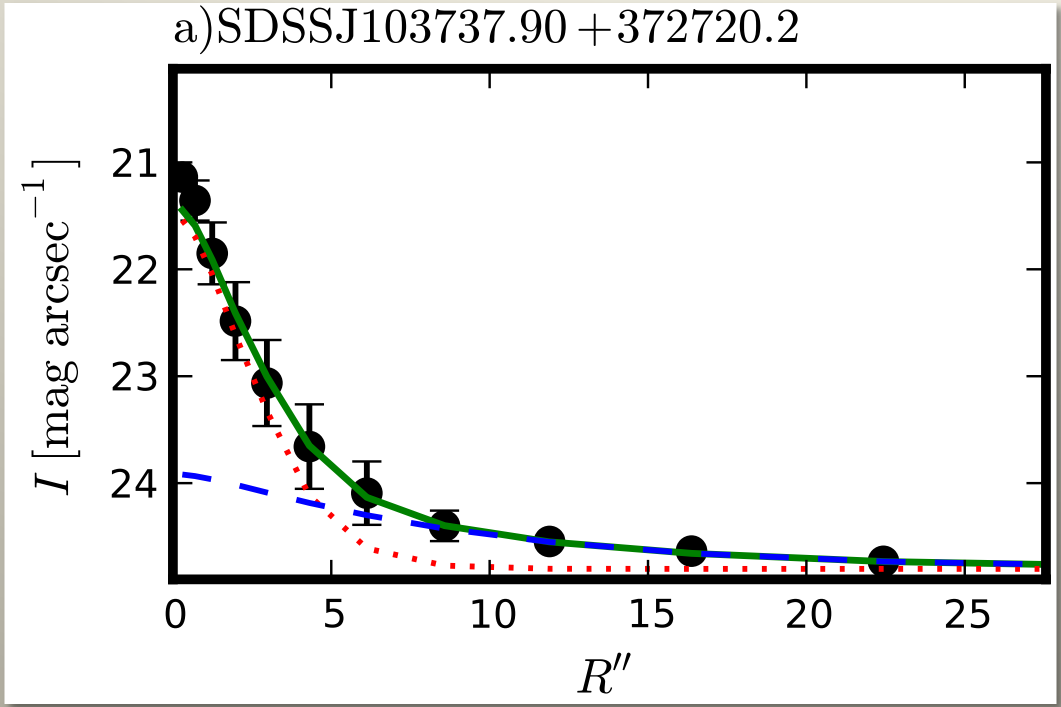
Pseudo-bulges are disk-like (n≈1)

Pseudo-bulges are blue

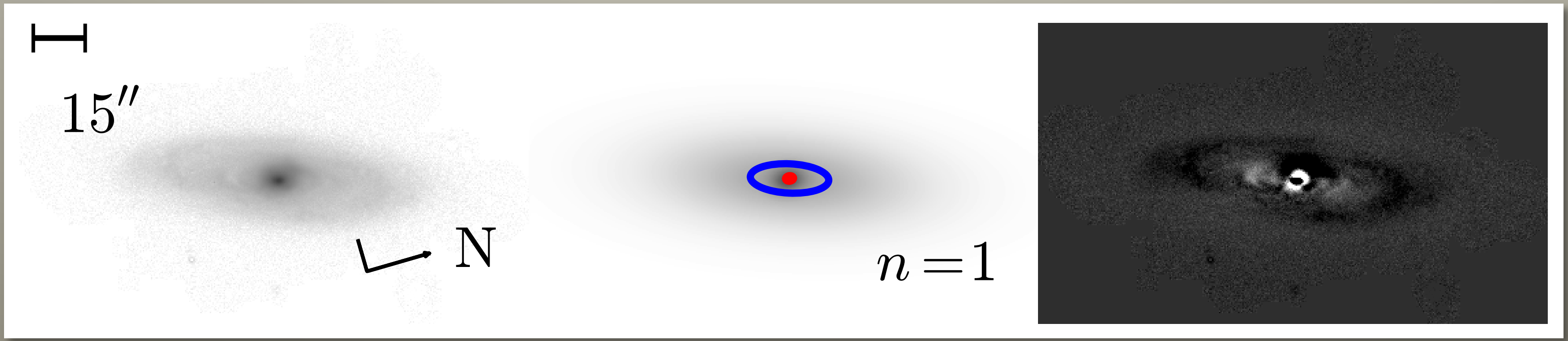


Gadotti, 2009

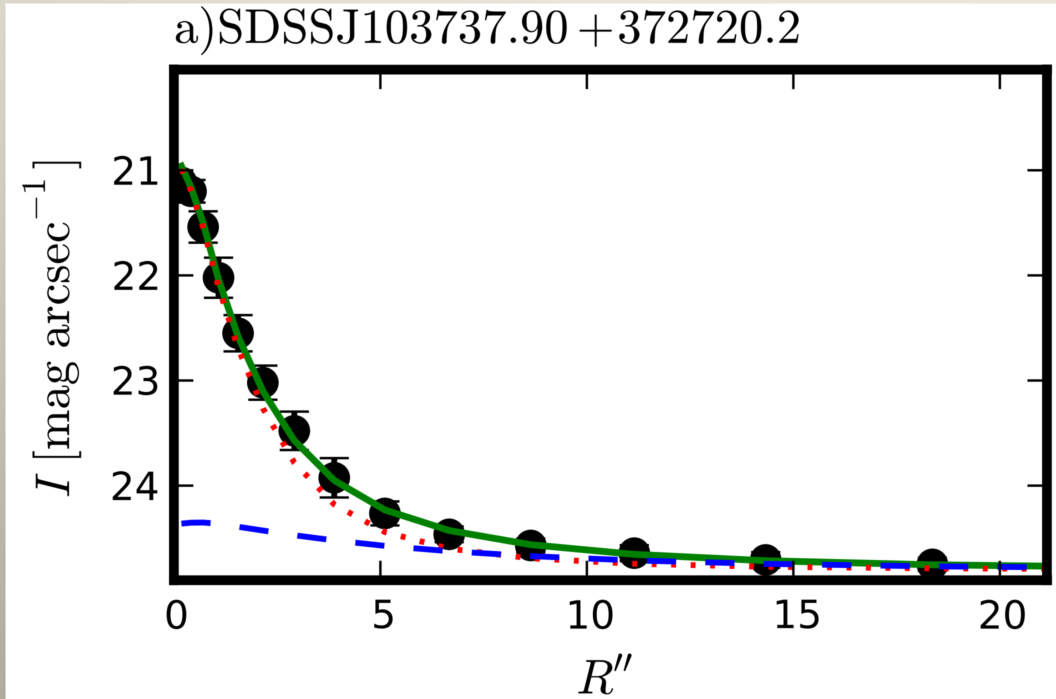
Pseudo-bulge



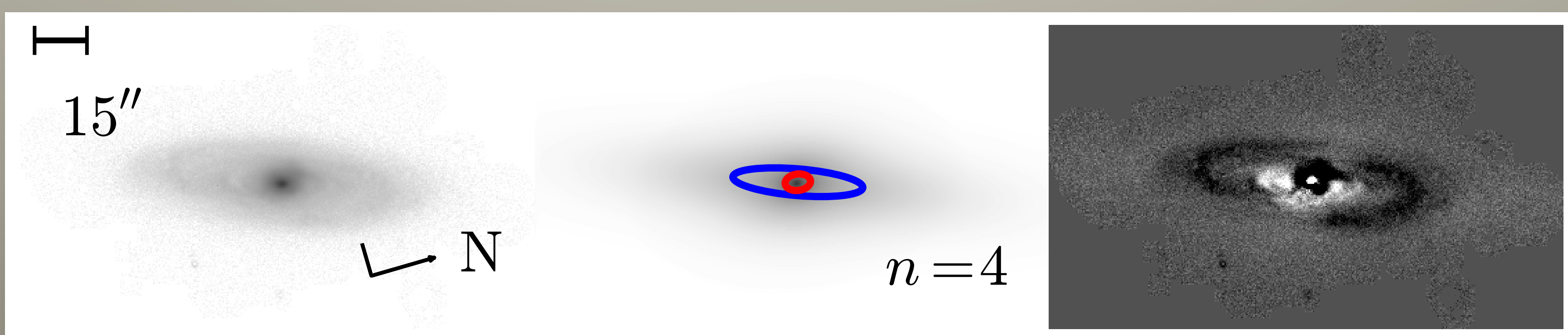
$$\chi^2 = 1.55$$



Classical Bulge



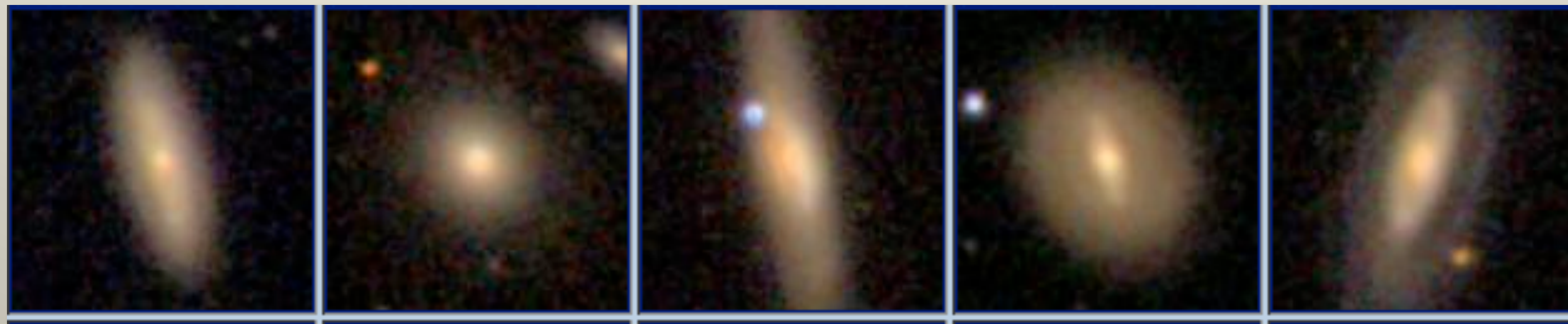
$$\chi^2 = 1.24$$



Spirals—"no" bulge

Ellipticals—all bulge

Disks with classical bulges



Disks with pseudo-bulges

Pseudo-bulges are distinguished from classical bulges using bulge color and flattening

Galaxies that are hard to fit

40% of the galaxies in the sample don't have physically meaningful bulge+disk fits

Categorizations

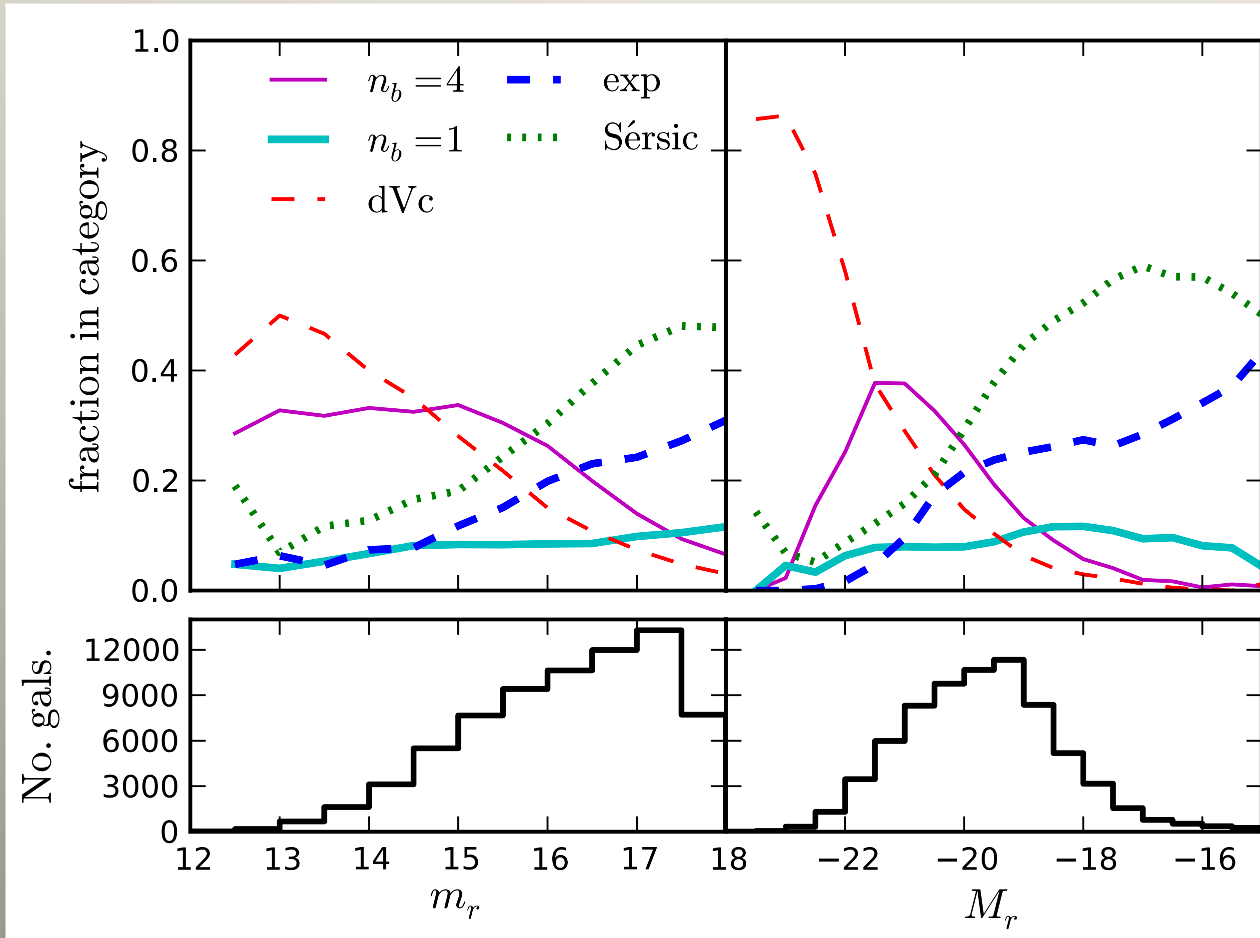
By Number

- 19% classical bulge hosts
- 9% pseudo-bulge hosts
- 13% ellipticals
- 21% disks
- 38% uncategorized (Sérsic)

By stellar mass (Bell, 2003)

- 31% classical bulge hosts
  - 20% bulges
- 7% pseudo-bulge hosts
  - 2% bulges
- 35% ellipticals
- 9% disks
- 18% uncategorized (Sérsic)

Magnitude Distributions



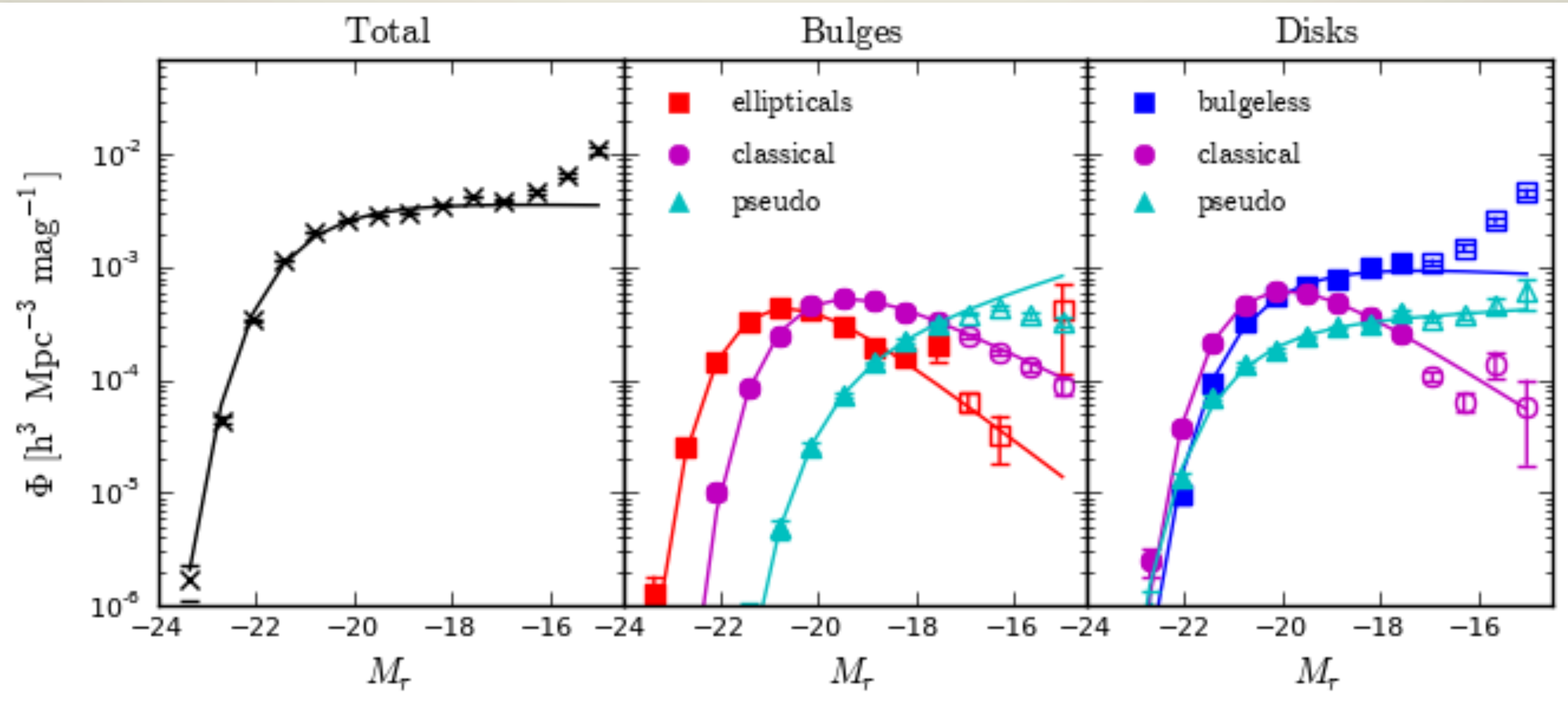
Apparent Magnitude

Absolute Magnitude

50% of the faintest galaxies are Sérsic profiles

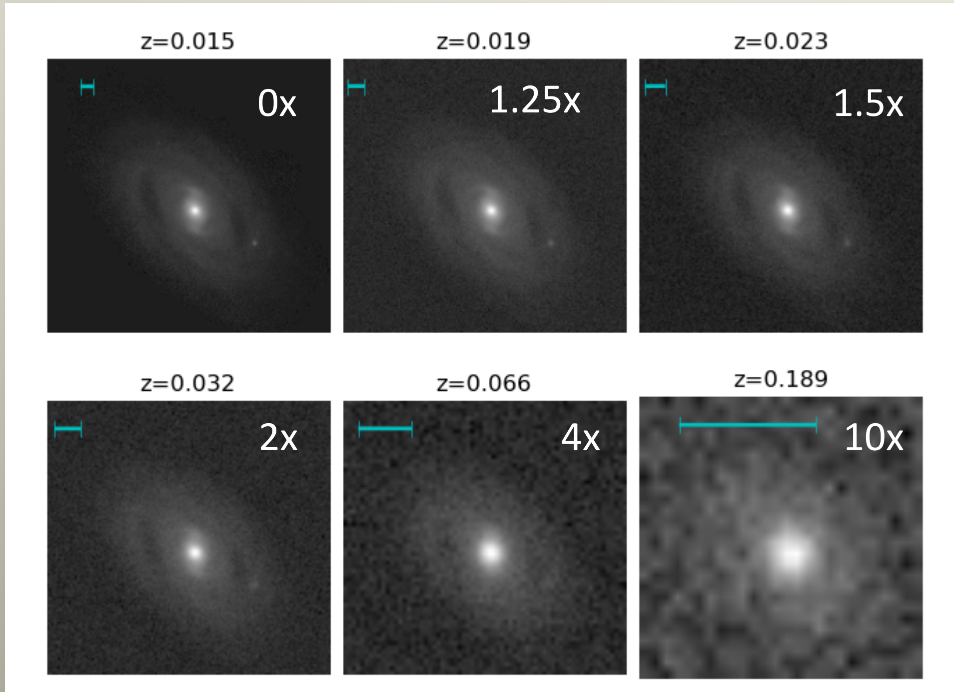
Intrinsically faint galaxies are Sérsic or exponential profiles

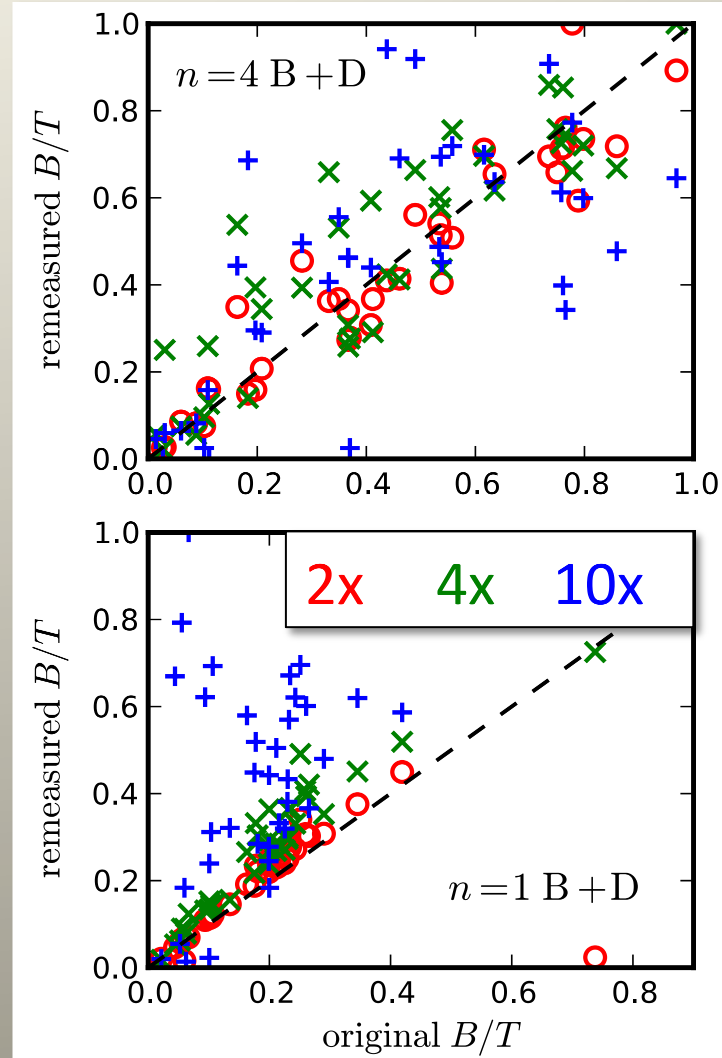
Luminosity Functions



Classical bulges have M_* 0.8 magnitudes fainter than ellipticals

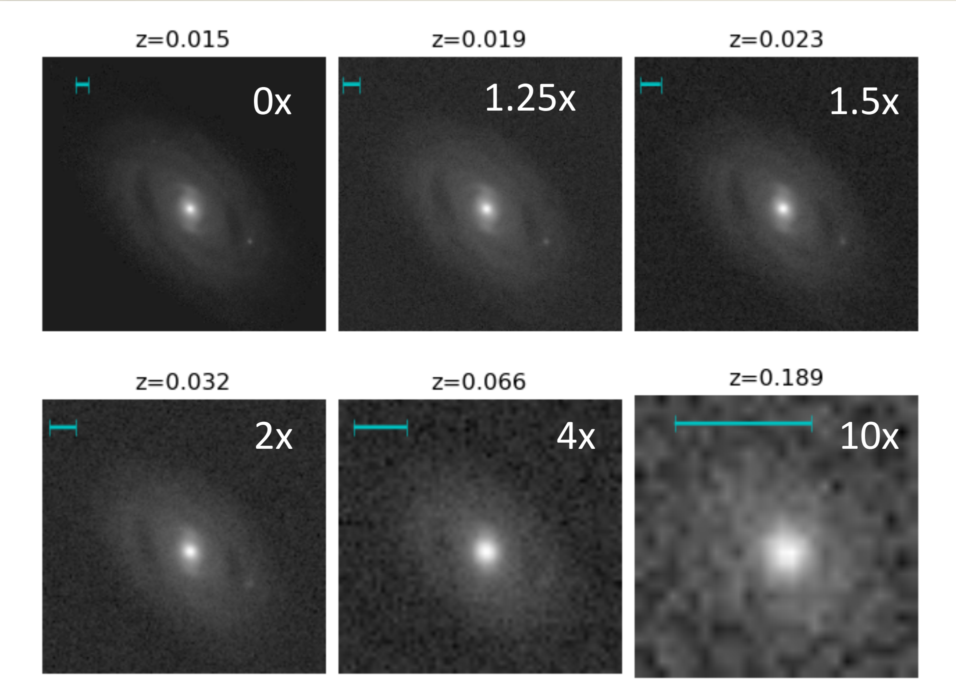
Redshifted Galaxies

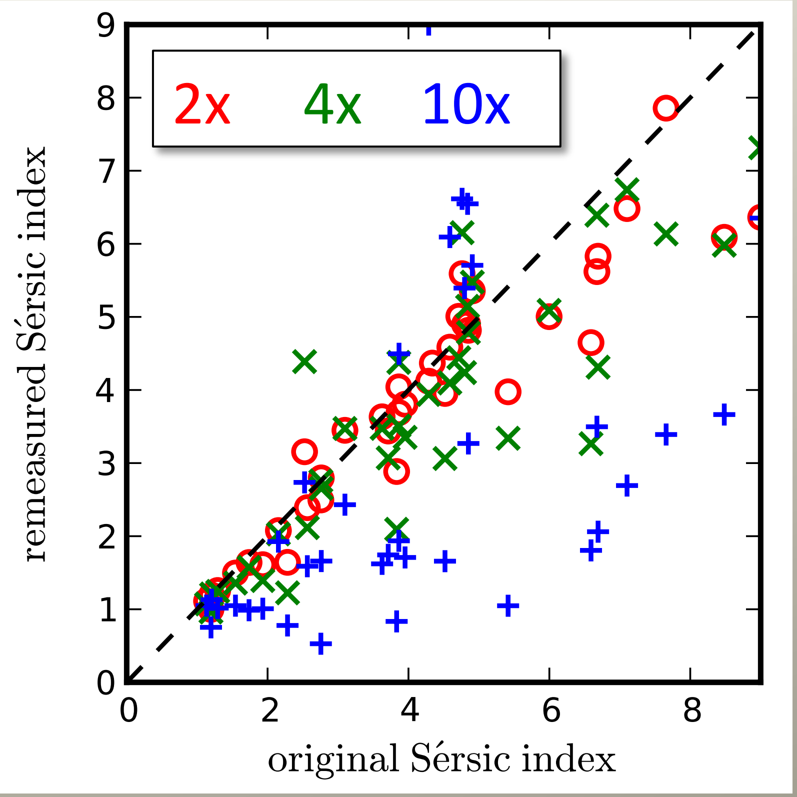




Scatter in B/T and Sérsic index is significant as a function of redshift

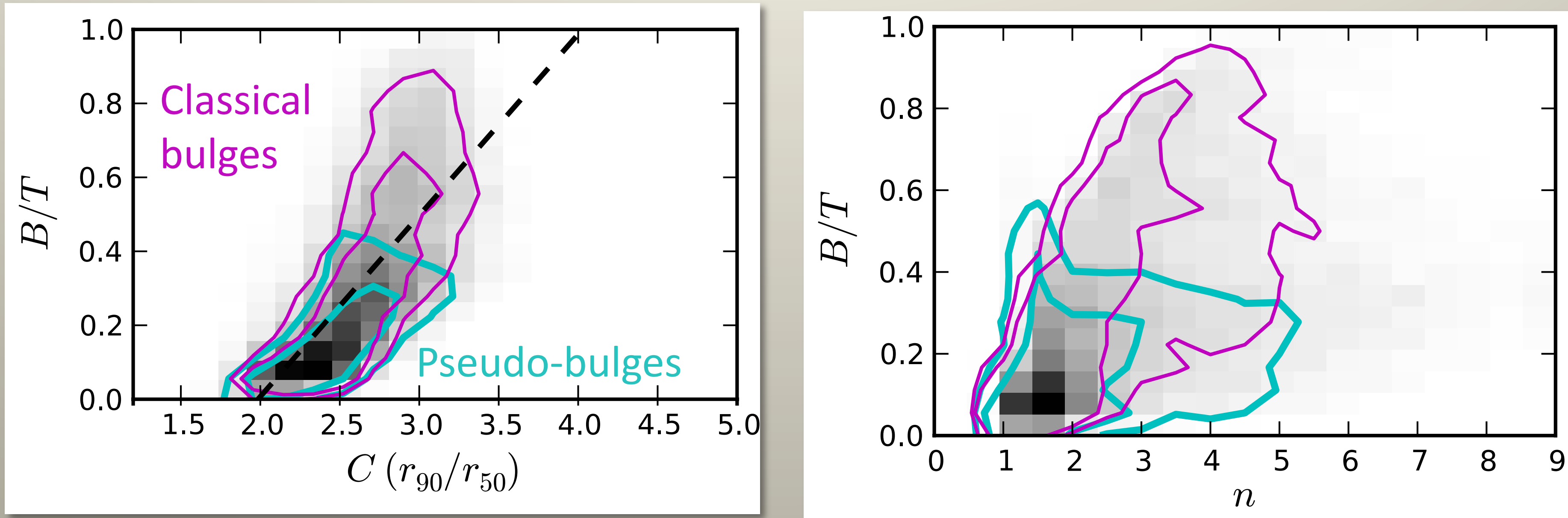
Redshifted Galaxies





Scatter in B/T and Sérsic index is significant as a function of redshift

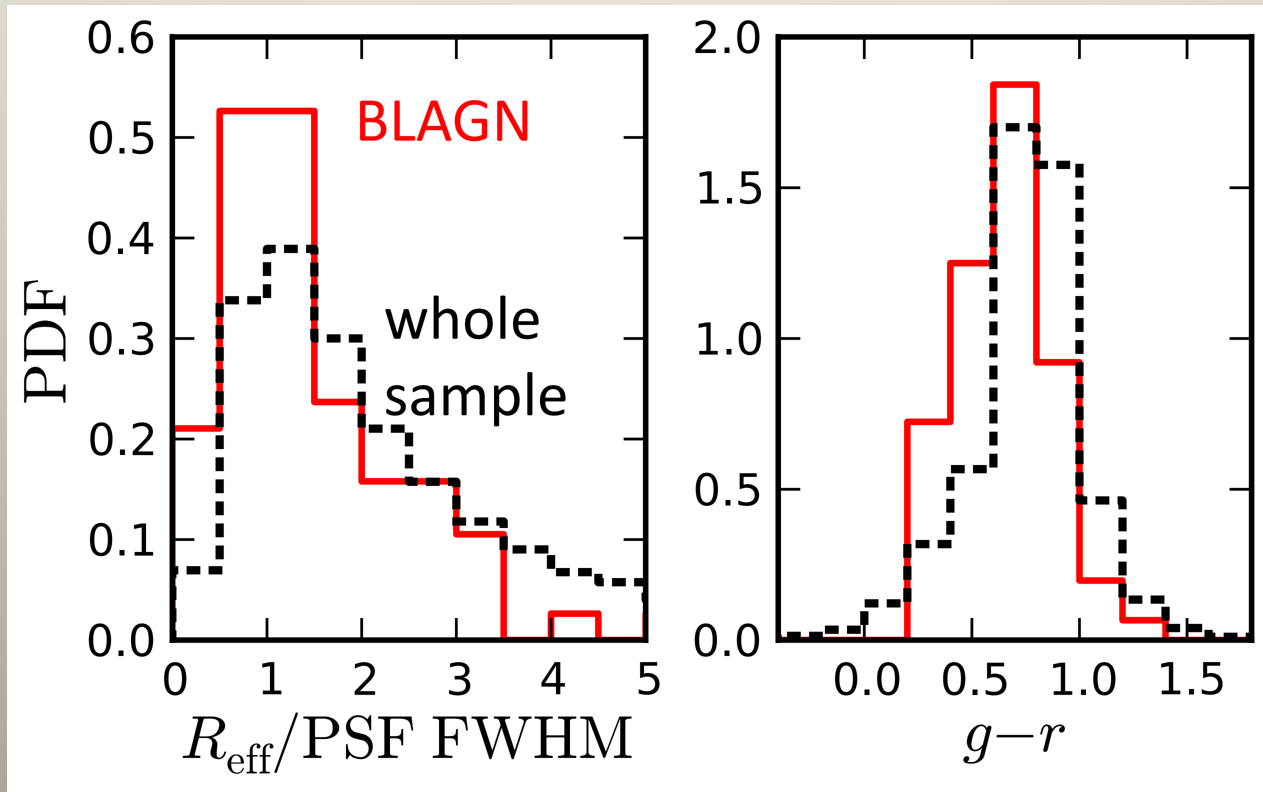
Bulge/Total Proxies



$$B/T = 0.4162 \times C - 0.7841$$

Concentration is better proxy for B/T than (total galaxy) Sérsic index, at resolutions such that seeing effects are small.

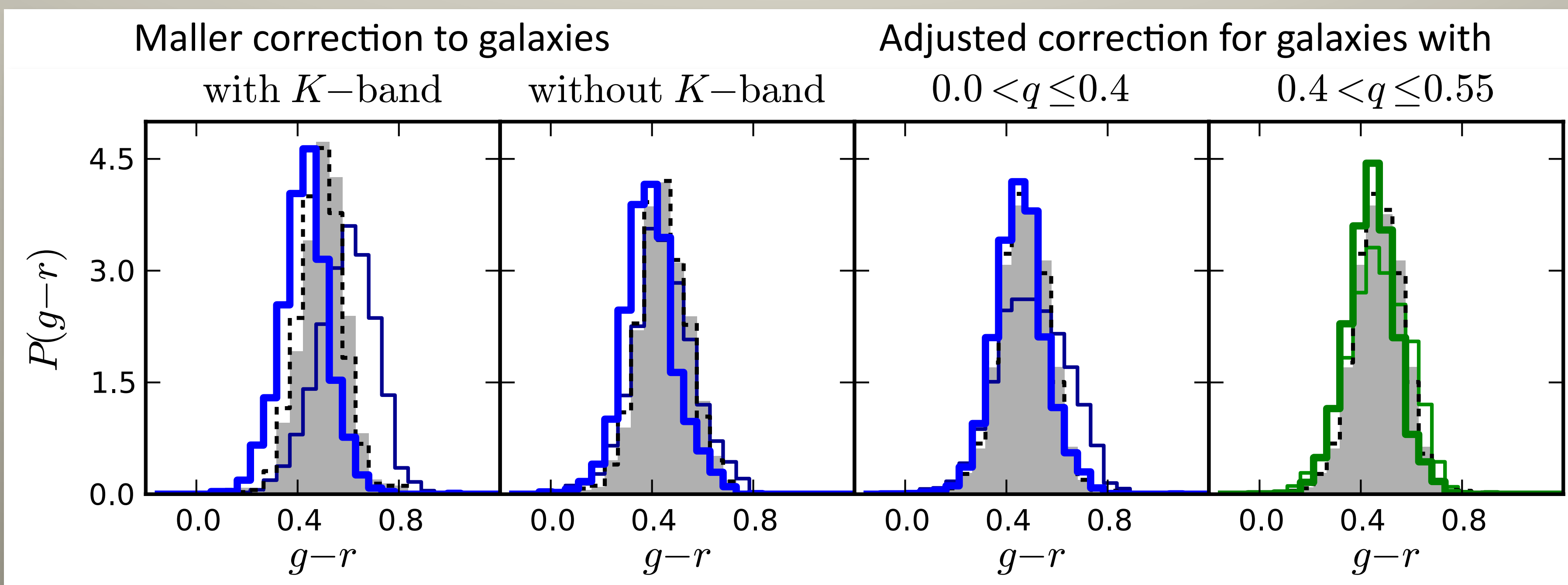
Contamination from AGNs



- <2% of sample is spectroscopic broad-line AGN
- Colors and sizes of BLAGN-host bulges are not significantly different

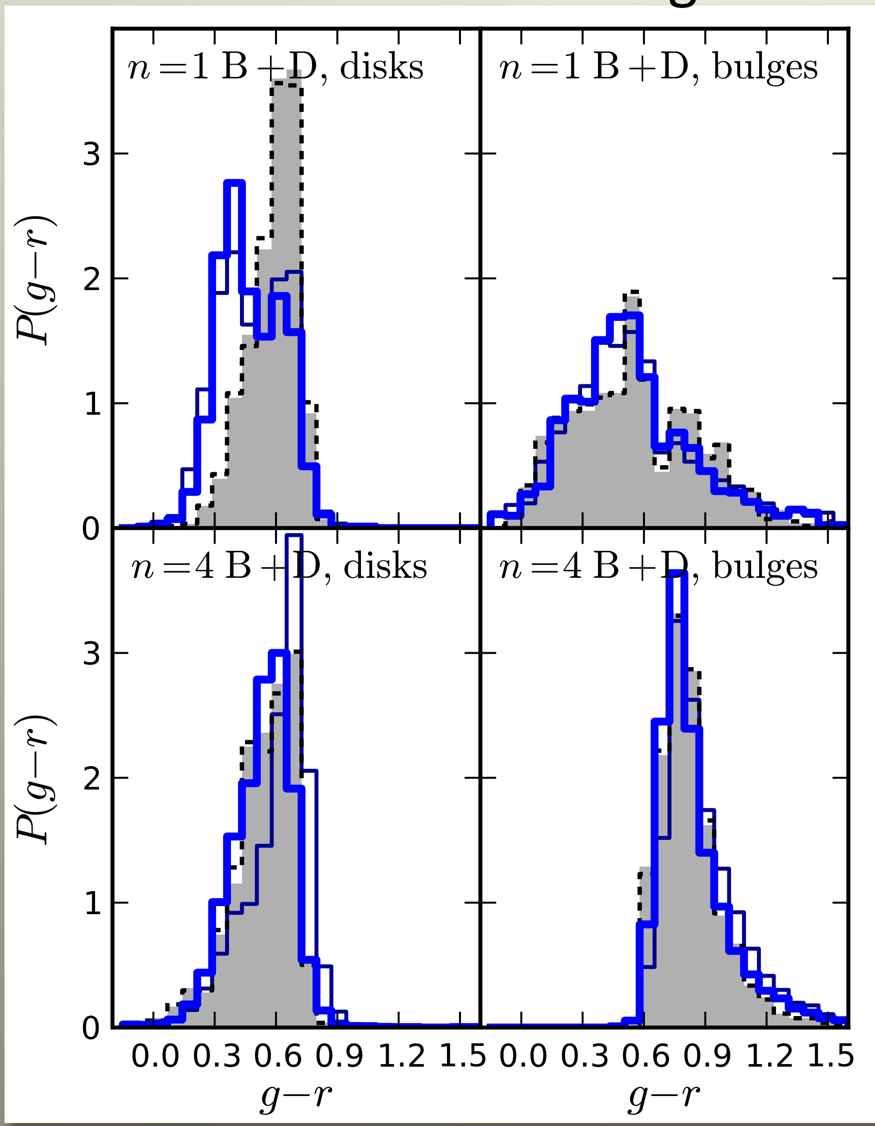
Inclination Corrections

- Based on Maller, et al. 2009—removes trends in K_s-band colors with disk inclination + adjustment
- Correction small for data without 2MASS observations



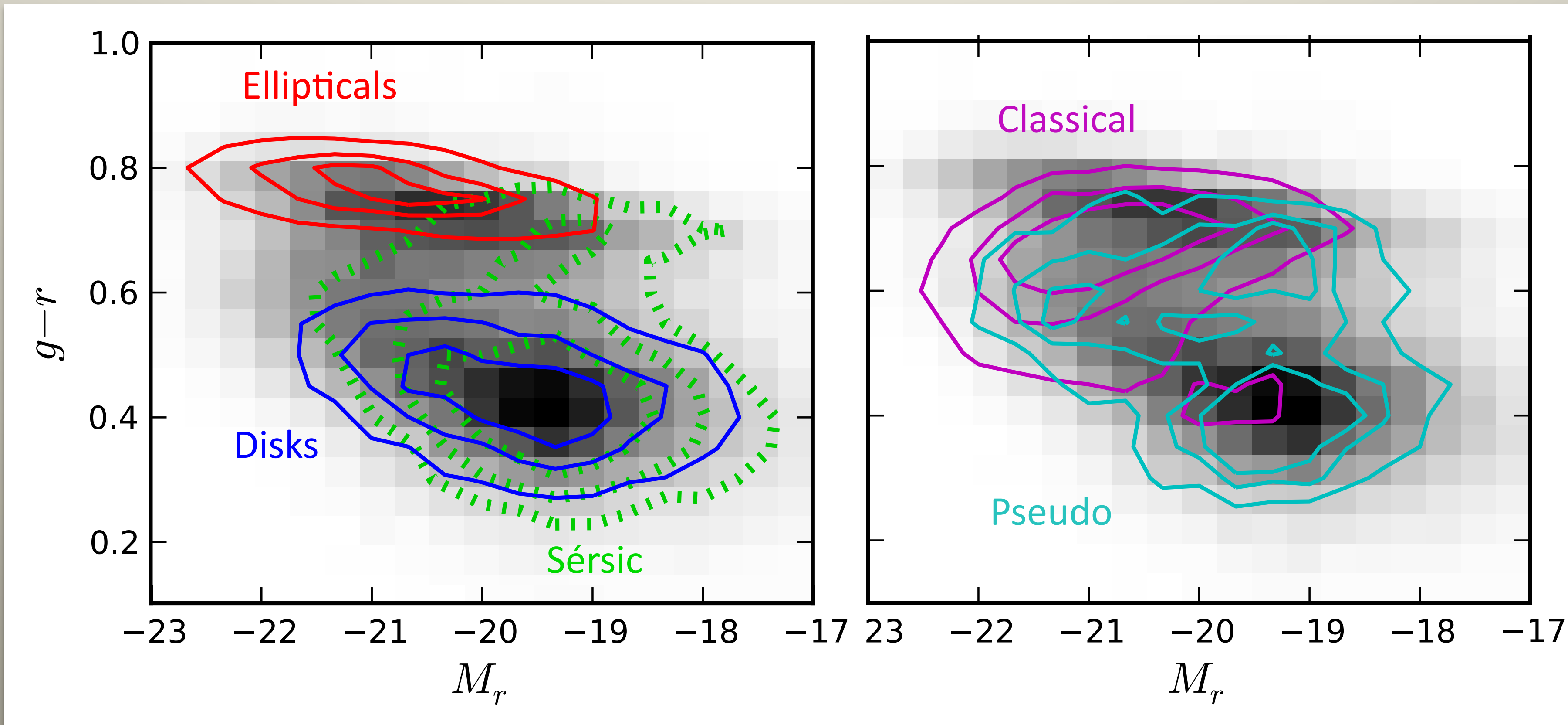
Inclination Corrections

Disks Bulges

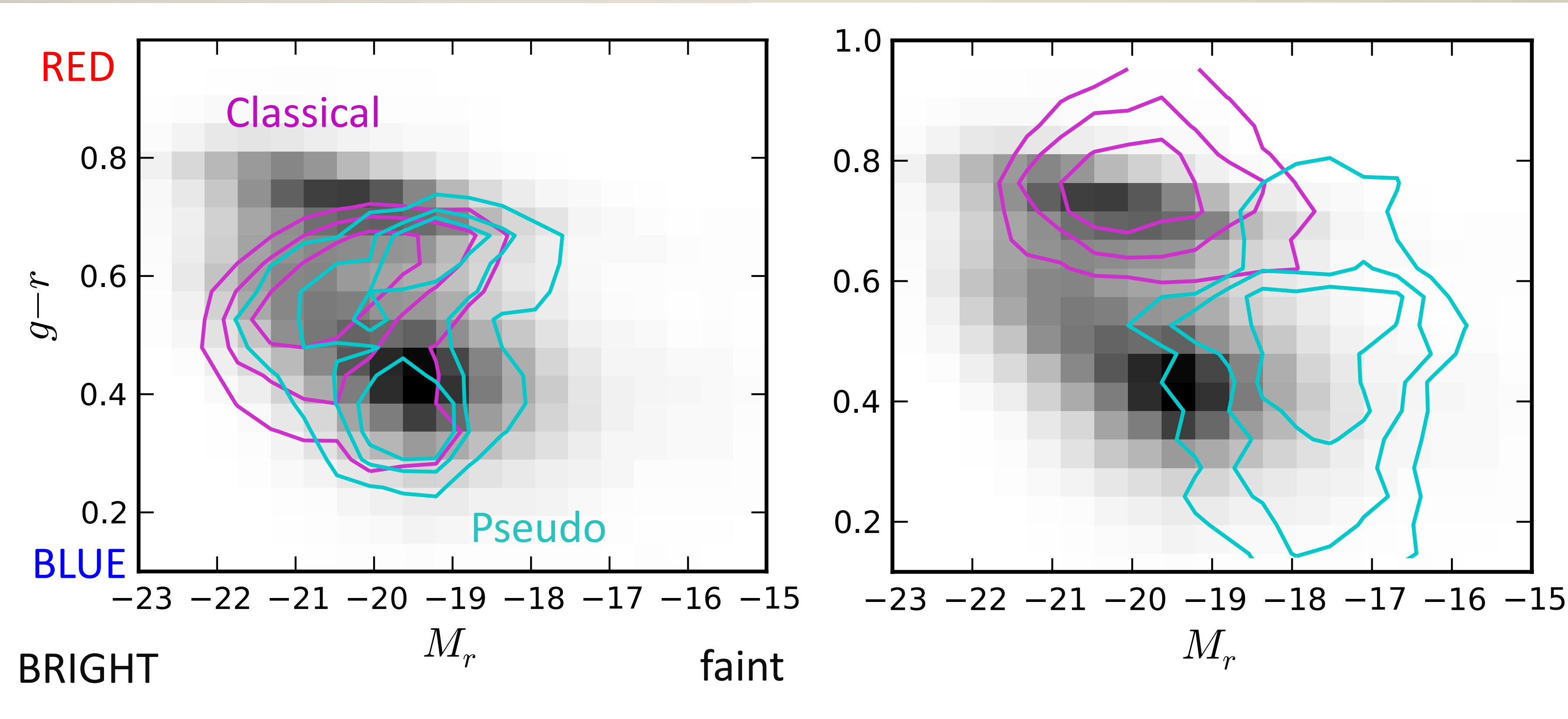


- Only ½ the bulge flux is inclination corrected for extinction from disk
- Correction is poor for fainter/bluer pseudo-bulge hosts

Color—Magnitude



Disk Colors Bulge Colors

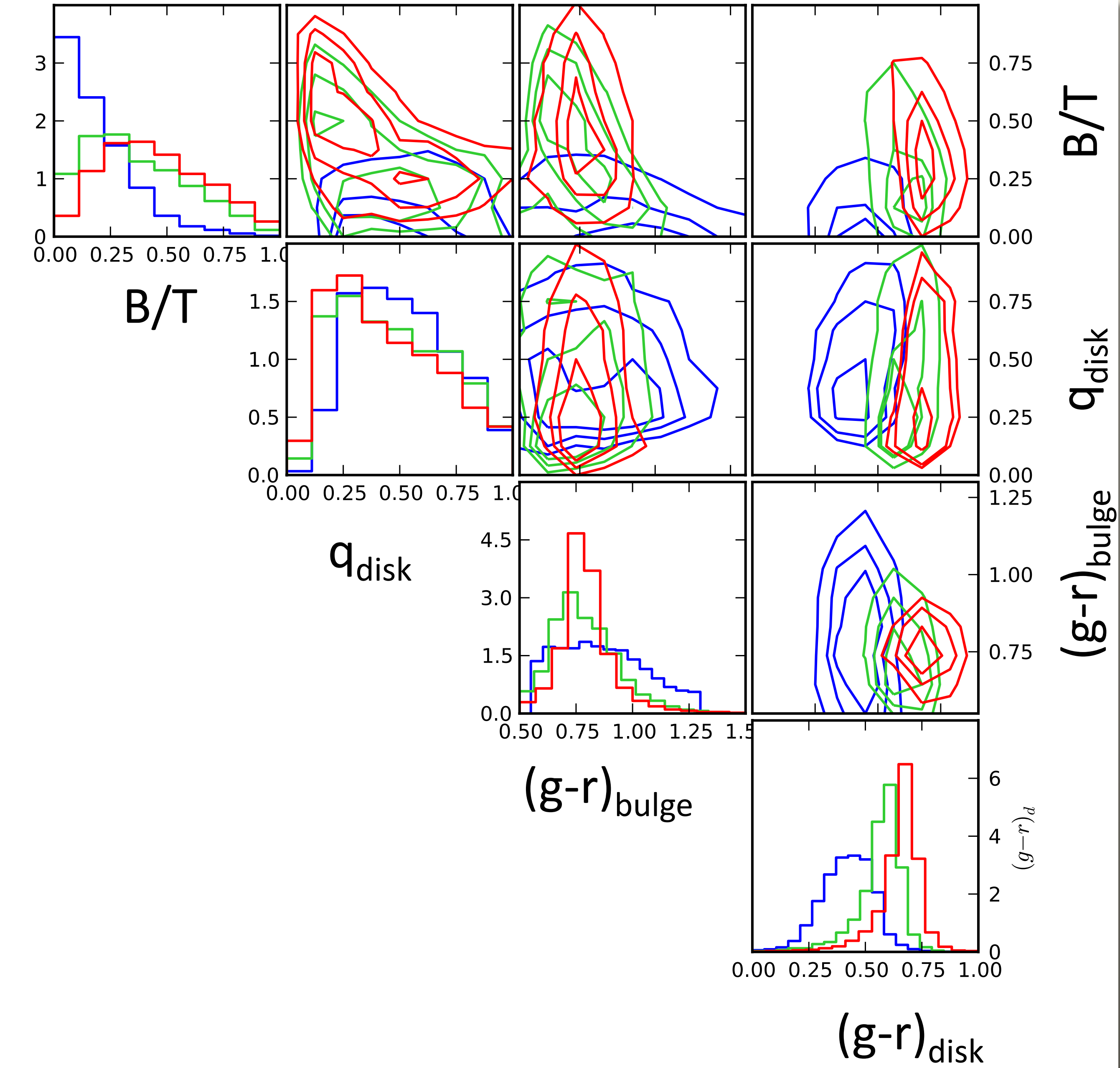


Red Sequence (8,657 gals.): (g-r) > −0.025(M_r + 20) + 0.661

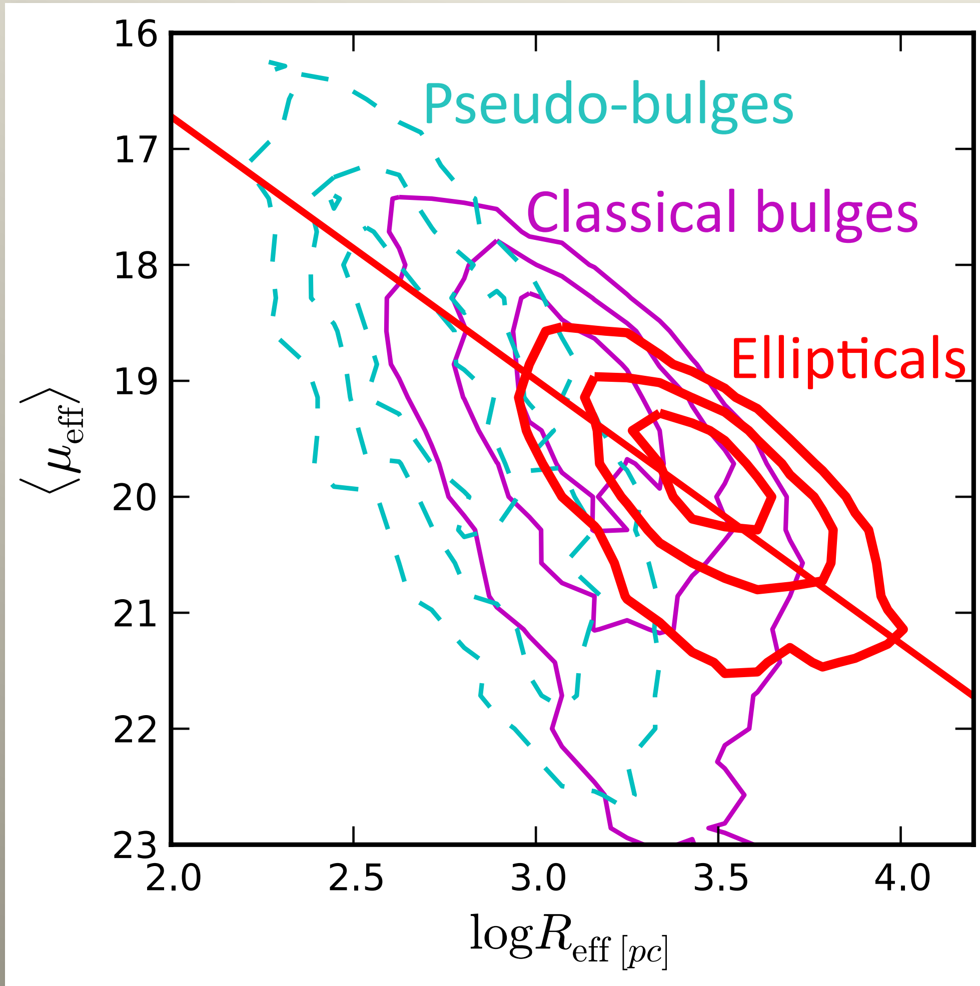
Green Valley (5,889 gals.): −0.025+(M_r + 20) + 0.661 > (g-r) > −0.025(M_r + 20) + 0.561

Blue Cloud (5,956 gals.): (g-r) < −0.025+ (M_r + 20) + 0.561

Green vs. Red: galaxies have redder disks and slightly larger bulges



Kormendy Relation



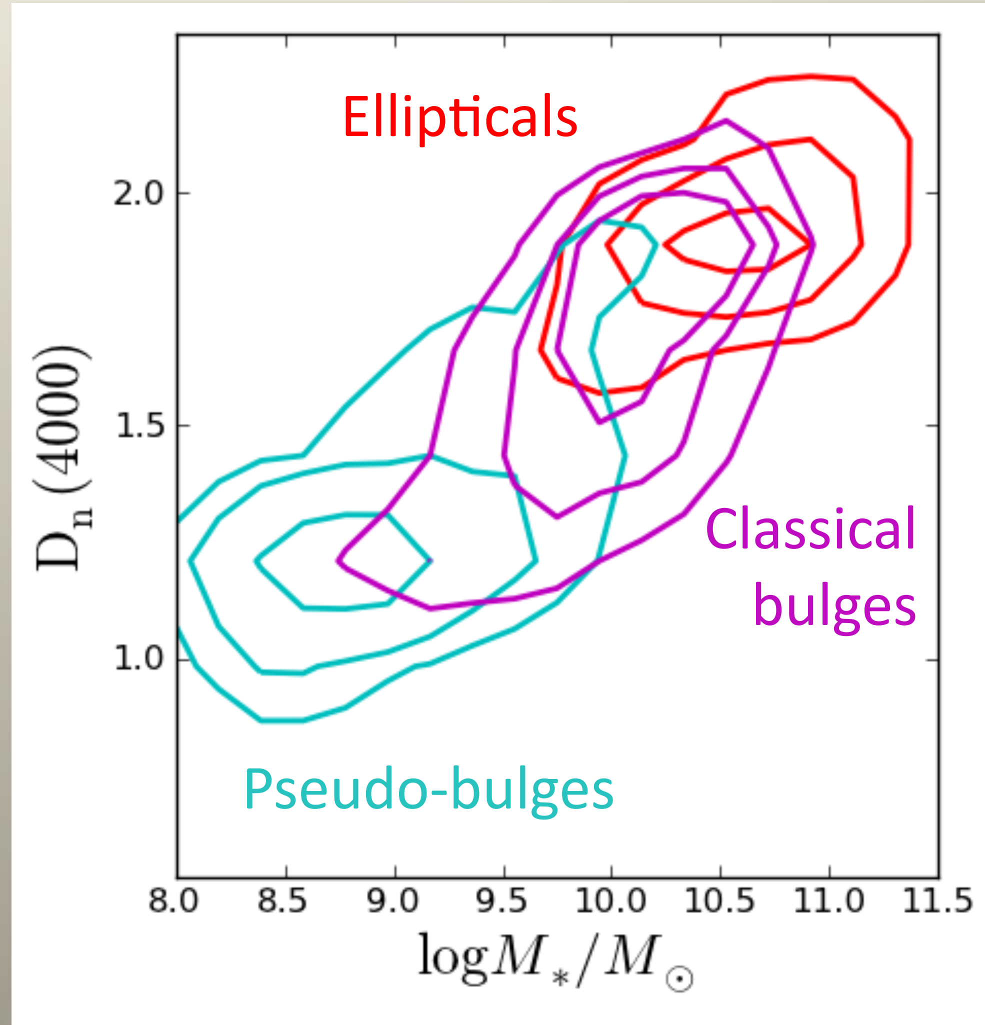
Classical bulges are better aligned with elliptical galaxies.

Agrees with Gadotti, 2009 division of classical/ pseudo by Kormendy Rel.

4000 Å Break

Classical bulges are older and more massive than pseudo-bulges.

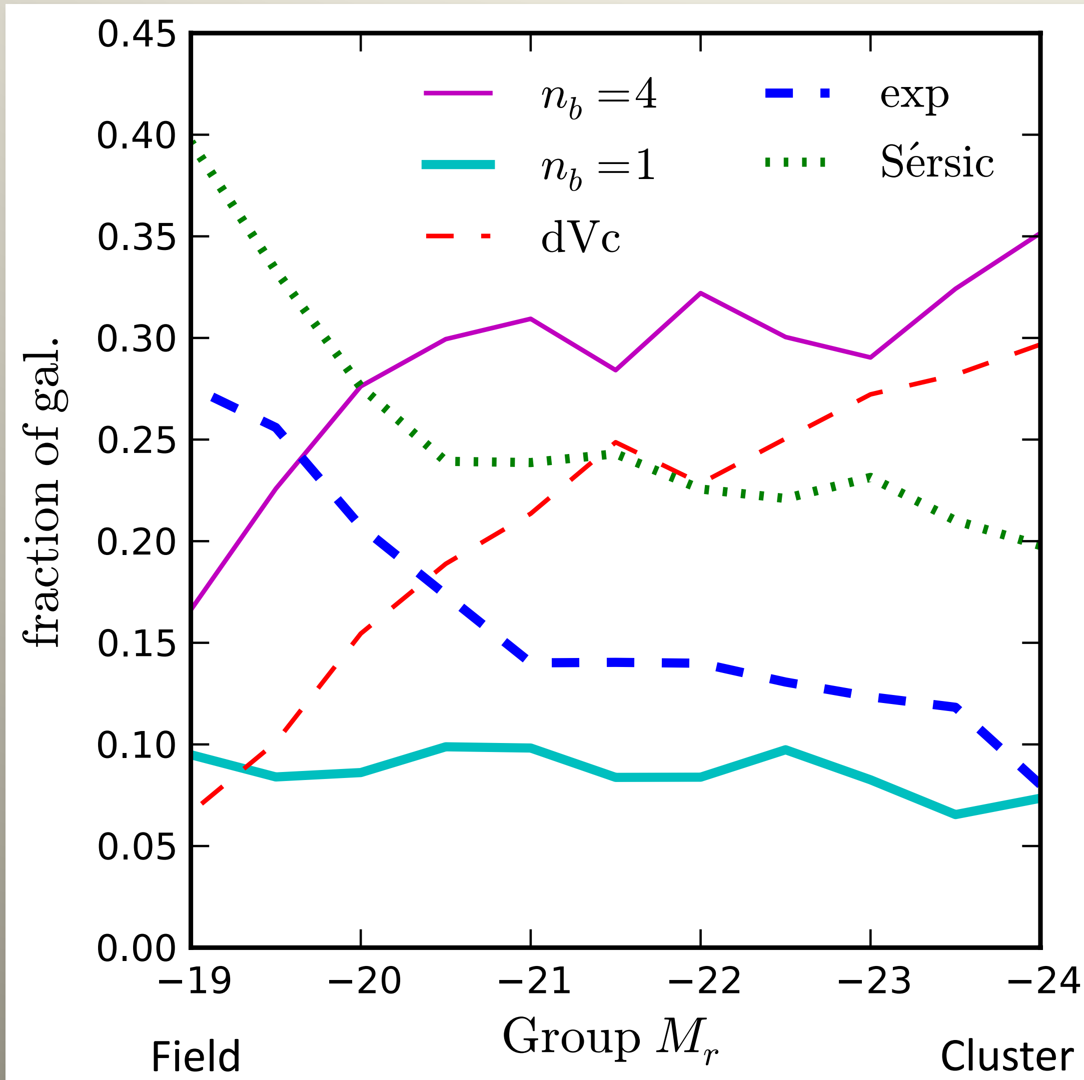
At a given mass, classical bulges have $D_n(4000)$ similar to that of ellipticals.



Classical Bulges and Ellipticals

- Classical bulges have the same colors, size-density correlations, and stellar ages as ellipticals
- Ellipticals form via mergers
- Disk galaxies form via cold gas accretion
- Why do some ‘ellipticals’ acquire disks while others do not?

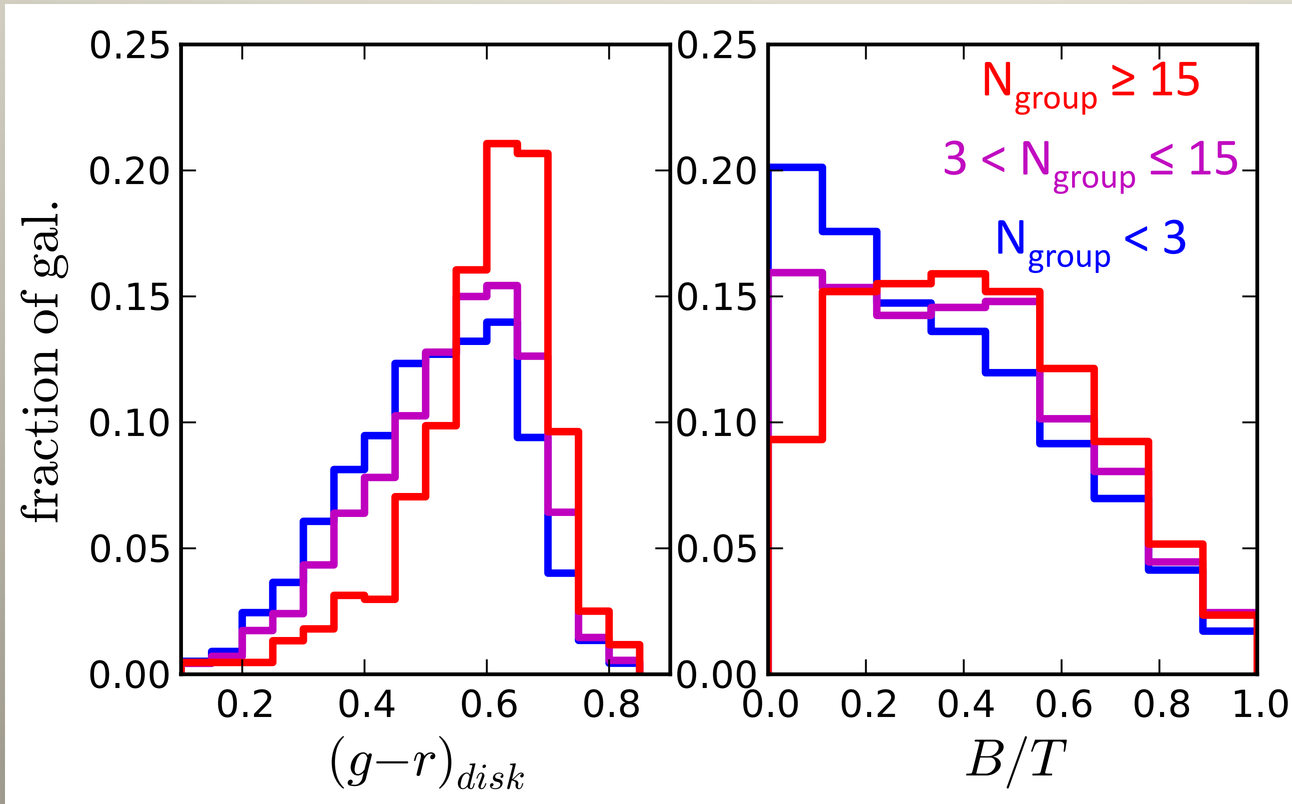
Density Morphology Relation



Galaxy populations are bulge-dominated at high densities.

Environment must play a role in disk formation/evolution.

Density Morphology for Classical Bulge Hosts



Richer Environment

➔

Redder disks and larger bulges

Conclusions and Future Work

- 2-dimensional B+D decompositions are successful for nearby, intrinsically bright galaxies with ($M_r \lesssim$ -18)
- Classical bulges can be separated from pseudo-bulges based on color and shape, these bulges are ‘ellipticals surrounded by a disk’
- How do the disk properties of classical bulge hosts change with environment?
- Does a classical bulge get a disk or not based primarily on environment?